Multi-Frequency Airborne Radar Measurements Over Byrd Glacier

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Introduction

Outlet glaciers and ice streams are the delivery systems of inland ice to the ocean, and for sea level change, a lot is riding on their future behavior. As the largest outlet glacier draining ice from East Antarctica, Byrd Glacier is playing a big role right now, contributing about a fifth of the ice going into the Ross Ice Shelf. When viewed from space, Byrd Glacier is as distinctive on a satellite image to the untrained eye as a hurricane over the ocean would be. Its rough surface, crevasses formed as the ice flows through a channel confined by rock sidewalls and a hard bed, can be distinctly seen as it flows into, and is buttressed by, the Ross Ice Shelf (Fig. 1). A large volume of surface elevation and surface velocity data has been compiled on this glacier since aerial photogrammetry was conducted in the 1980s.

However, understanding the ice dynamics of Byrd Glacier using numerical models has been hampered by the lack of detailed bed topography data. The CReSIS airborne field program is aimed at simultaneously collecting ice thickness and surface elevation data using a suite of radar instruments. These data sets will be combined to produce detailed measurements about bed topography, which is essential for understanding and predicting the current and future mass balance of Byrd Glacier.

Our field plan is to collect radar data over a fine scale grid of Byrd Glacier using the CReSIS instrument suite. Over 26,000 km of flight lines will be covered in roughly 16 flight missions. Two fuel caches were staged to support this operation. There are two main scientific areas of interest: the trunk of Byrd Glacier, and the catchment area where previous studies have identified two active subglacial lakes. The topography under the trunk is important for understanding the location and stability of the grounding line and the resistance that large subglacial features can provide to ice flow. In the catchment region, scientists are interested in understanding the topography underlying and adjacent to the subglacial lakes.

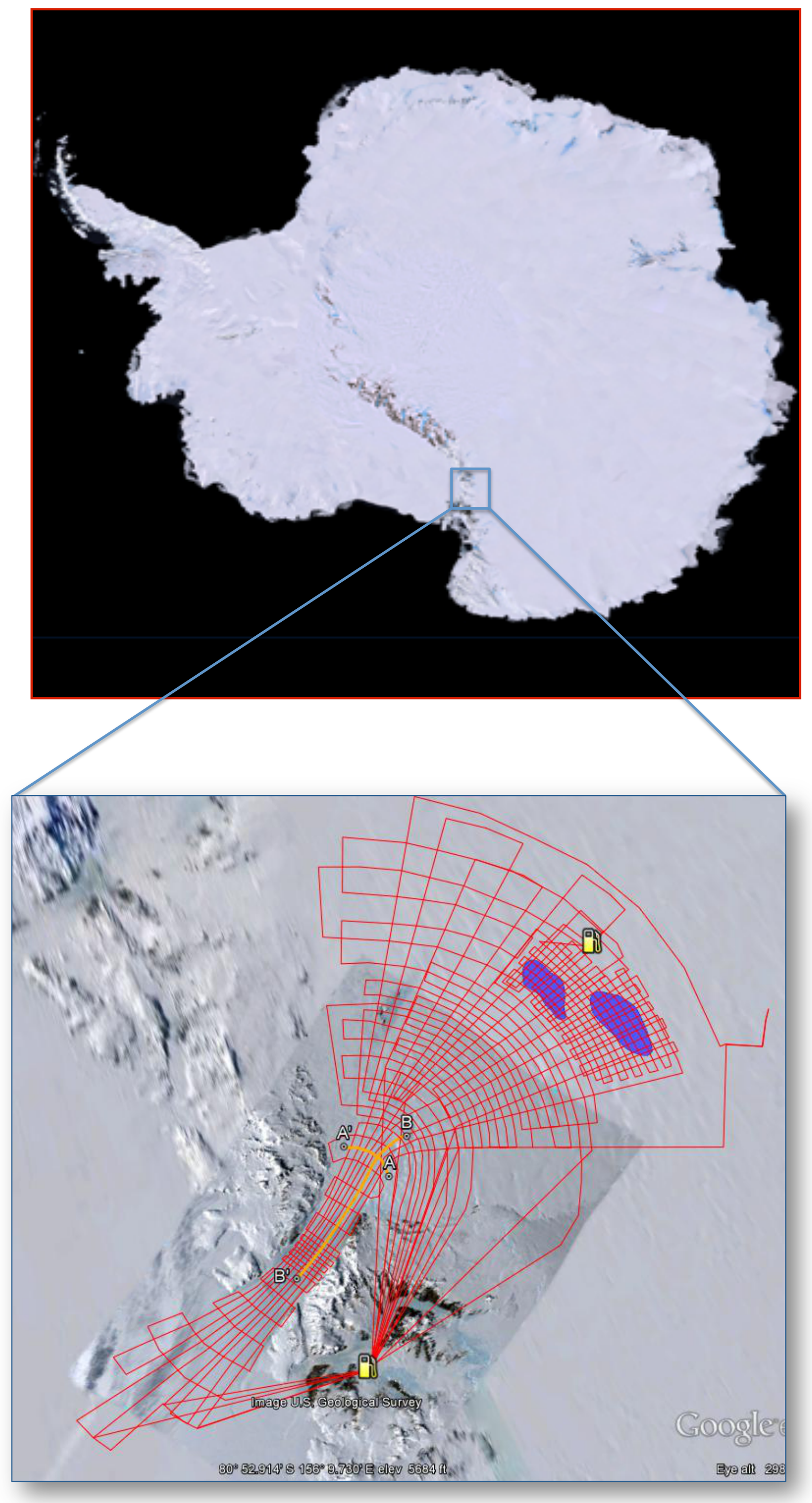

Fig. 1: Satellite images of Antarctica and Byrd Glacier. The planned flight lines are marked in red. The locations of the subglacial lakes are marked in blue. Sources: http://landsat.usgs.gov and Google Earth.

Fig 2. Photograph taken from the Twin Otter aircraft showing the crevassed ice surface along the channel of Byrd Glacier. Photograph credit: J. Li.

CReSIS Radar Instrument Package

The CReSIS radar instrument suite is designed to provide coincidental measurements at multiple frequencies over the target of interest (Fig. 3). Our unique remote sensing package is composed of three radars and ancillary systems. The first radar operates at VHF (195 MHz with 30 MHz of bandwidth) and is capable of sounding a few-kilometer thick ice and mapping the ice-bedrock interface and internal layers. The second instrument operates at UHF (750 MHz with 300 MHz of bandwidth) and is primarily used to map annual layer thickness in the upper Byrd glacier to a depth of a few hundred meters. When flying over ice shelf or in areas where the ice is shallow, the UHF radar can also profile the bedrock topography with very high resolution. The third component to the instrumentation package is a UWB system operating at microwave (Ku band) frequencies with 6 GHz of bandwidth (12-18 GHz). This radar used to measure surface topography as well as mapping shallow sub-surface layers with centimeter resolution. Ancillary systems include an inertial navigation system (INS) and an onboard global positioning system (GPS) and a GPS base station. These systems combined provide precise aircraft attitude and position information. The airplane flies at a nominal altitude of 500 m above the ice surface. The antenna structures for the three radars are integrated with a Twin Otter aircraft so that the aerodynamic performance is not compromised (Fig. 4, Fig. 5). All the electronics associated with the radars and ancillary systems are installed inside the cabin (Fig. 6).

The radar depth sounder produces an average of 1.25 TB of data per flight, while the UHF and microwave radars produce an average of 400 GB combined. Data from all radars are backed up and processed on-site using a dedicated field computing facility. First-order results are typically available within 24-48 hrs after the completion of each mission.

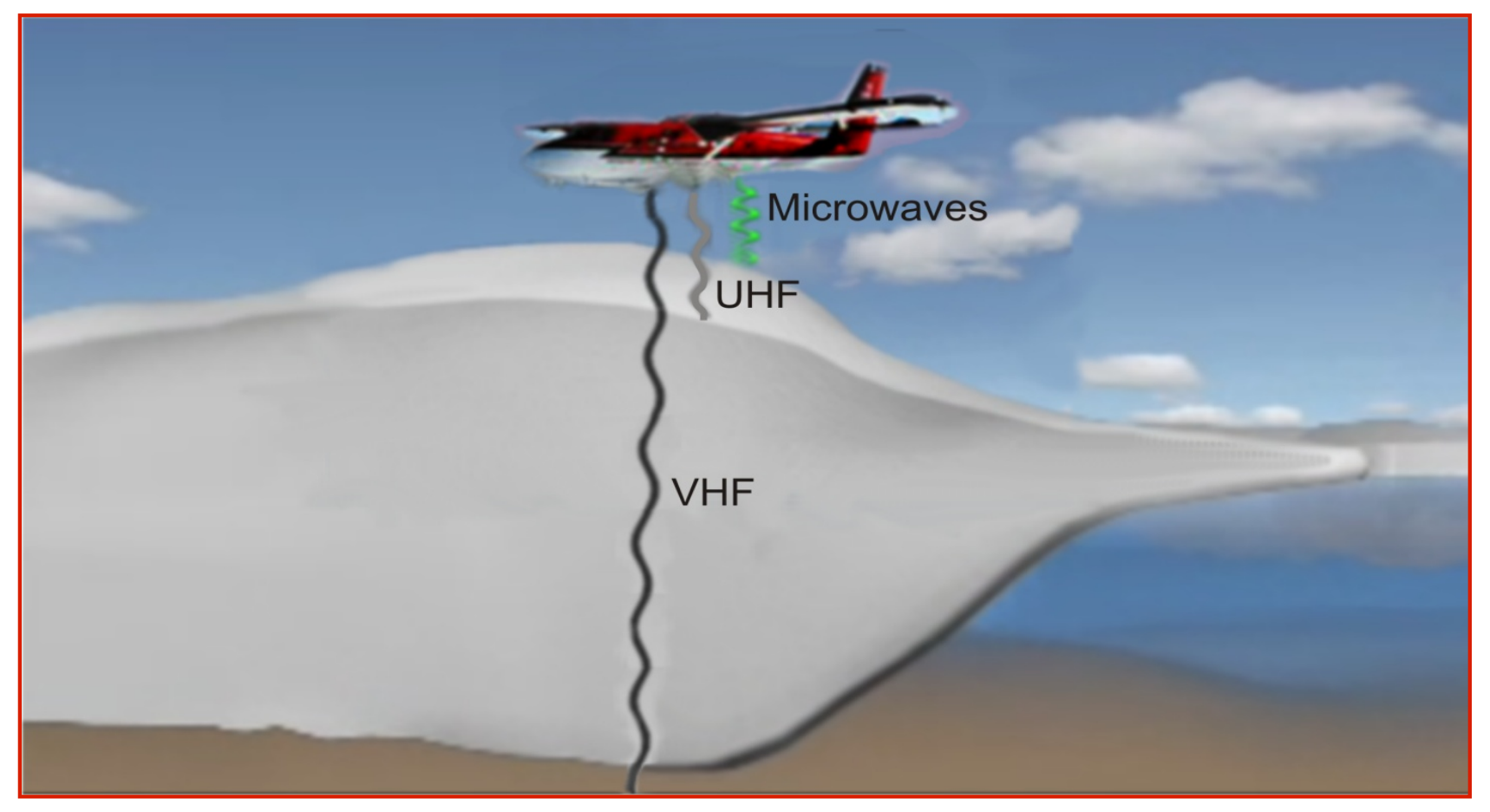

Fig. 3: Illustration of the simultaneous multi-frequency radar measurements performed with the CReSIS instrumentation suite over Byrd glacier. By using radar at different frequencies it is possible to penetrate to different depths in the ice column, obtaining fine-resolution measurements.

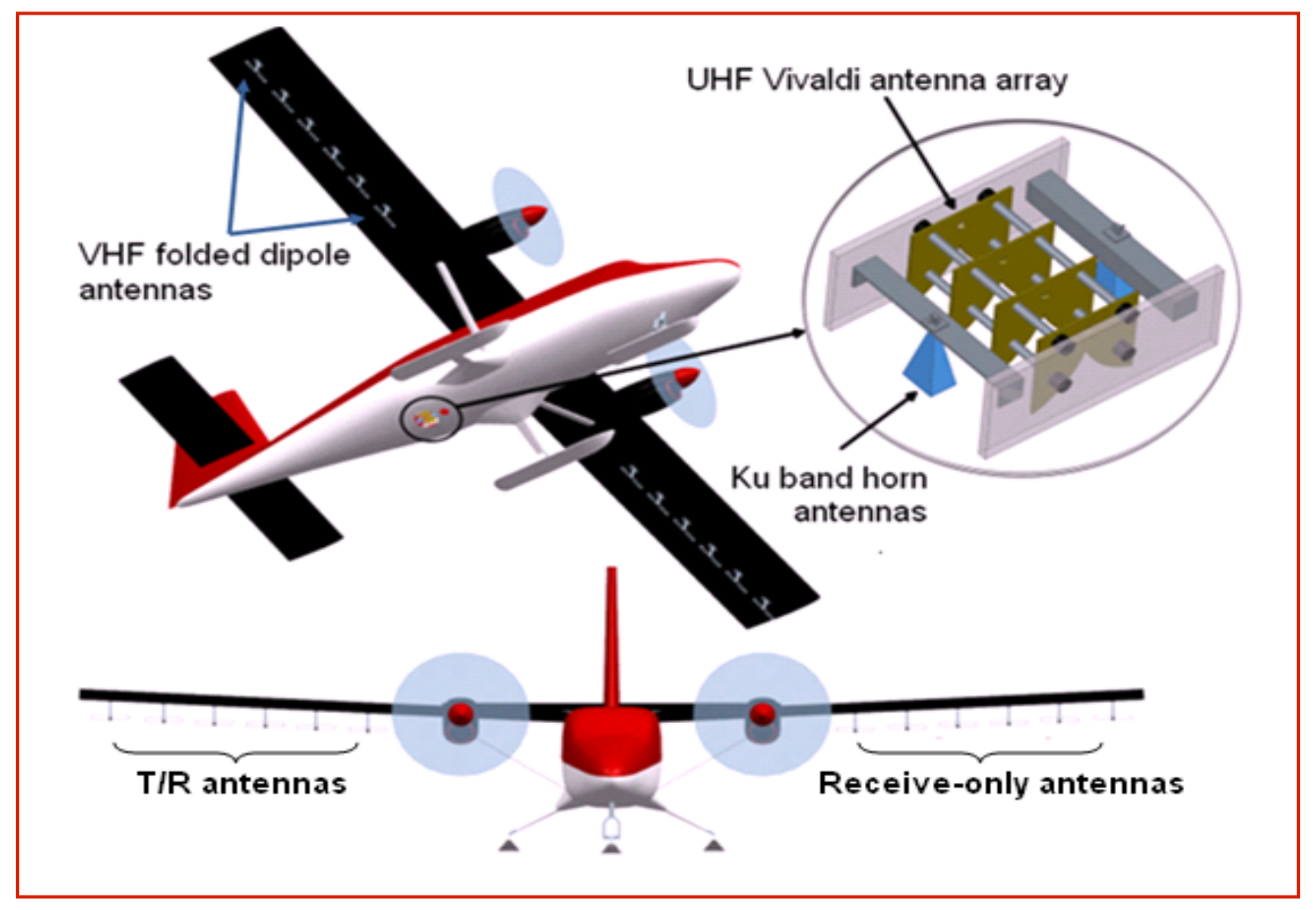

Fig. 4: Computer model illustrating the location of the three antenna structures used with the CReSIS radar suite. The antennas for the VHF depth sounder are installed under the wings, while the antennas for the other two instruments are installed on the nadir port of the aircraft.

Fig. 5: Photograph of the Twin Otter airplane with the CReSIS radar suite installed. Photograph credit: J. Miller.

Fig. 6: Photograph radar electronics inside the cabin of the Twin Otter aircraft. Photograph credit: J. Miller.

Sample Results

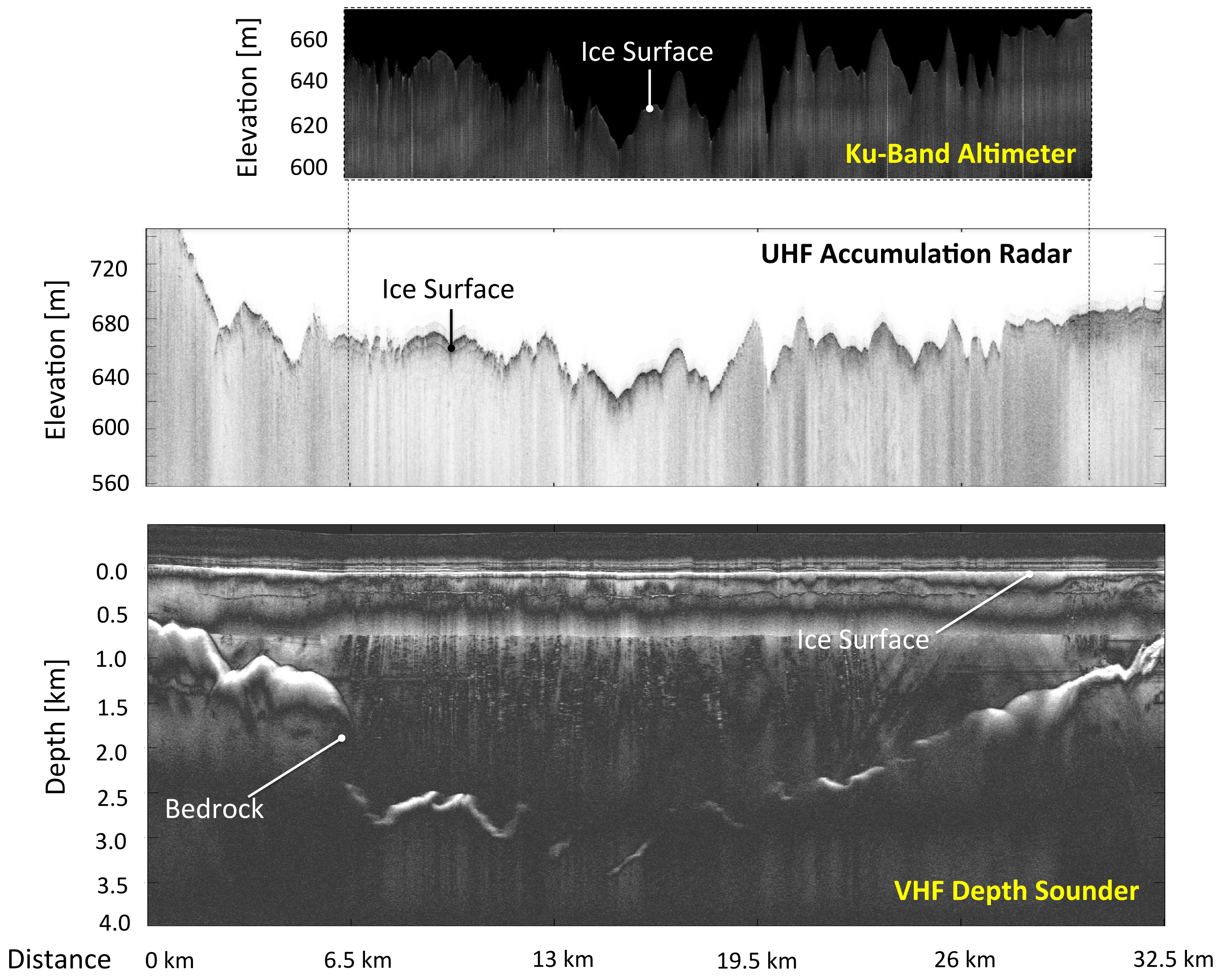

Fig. 7: Sample results obtained with the three radars for a 32-km section across Byrd glacier between points (80.609 S, 155.2E) and (80.833S, 156.04E). This segment is marked as A-A' in Fig. 1

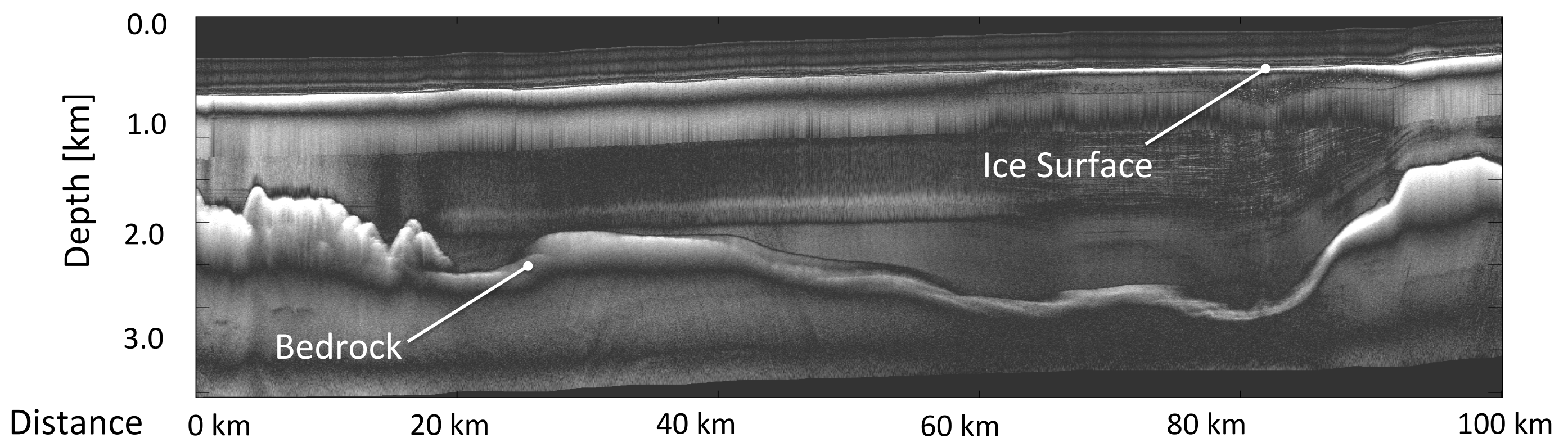

Fig. 8: Sample results obtained with the VHF depth sounder over a 100 km section along Byrd glacier between points (80.337 S, 158.89E) and (80.746S, 154.19E). This segment is marked as B-B' in Fig. 1

Acknowledgements

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